ИНЖЕНЕРНО-ТЕХНИЧЕСКИЕ СИСТЕМЫ. ЭКОЛОГИЧЕСКАЯ БЕЗОПАСНОСТЬ В СТРОИТЕЛЬСТВЕ И ЖКЖ

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A PERSPECTIVE OF INTEGRATED WATER RESOURCES MANAGEMENT IN THE YELLOW RIVER BASIN

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Хуанхэ является одним из важнейших водных источников Северо-Западного и Северного Китая. Быстрый экономический рост создает проблему дефицита водных ресурсов и угрозу загрязнения водных объектов. Периоды засухи в бассейне Хуанхэ начиная с 1990 г. ежегодно увеличиваются. Решение накопившихся проблем может быть найдено при использовании комплексного подхода к управлению водными ресурсами. Данное исследование предлагает рассмотреть административное регулирование водных ресурсов в бассейне Хуанхэ, строительство водных сооружений и привлечение общественности к проблемам использования воды.
Ключевые слова: *Желтая река, Хуанхэ, водные ресурсы, устойчивый, управление.*

The Yellow River is one of the most important water sources for northwestern and northern region of China. With the fast economic and social development, the demand for water resources greatly exceeds its supply and the deficit constrains the sustainable development in the YellowRiver Basin. Since the 1990's the extent and duration of drying-up in the Yellow River downstream have lengthened year by year. From a sustainable perspective, the strategy of Integrated Management Framework should be paid urgent attention. The framework aims to address the issues of non-balance between supply and demand, wastage, overexploitation, lengthening drying-up, and pollution in the YellowRiver Basin, and to establish a sound foundation for the effective development and protection of water resources in the region. This study presents the suggestions of reviewing the legal system concerning water resources, reforming the administration management system, improving water engineering framework, and establishing the public participatory framework.
Key words: *Yellow River, water resources, sustainable, management.*

1. Introduction

In recent years, the Yellow River, the second largest river in China, has been facing serious problems such as water resources shortage, flooding and ecological deterioration, while it holds a strategically important position in the regional economy layout of China (Fig. 1). The formation, evolution and reformation of the water resources follow the natural actions, but human's excessive social and economic activities have influenced the water cycle seriously.

Consequently, the sharp unbalance between supply of and demand for water resources comes out, and environmental degradation is incurred, which blocks the sustainable development of the Yellow River basin.

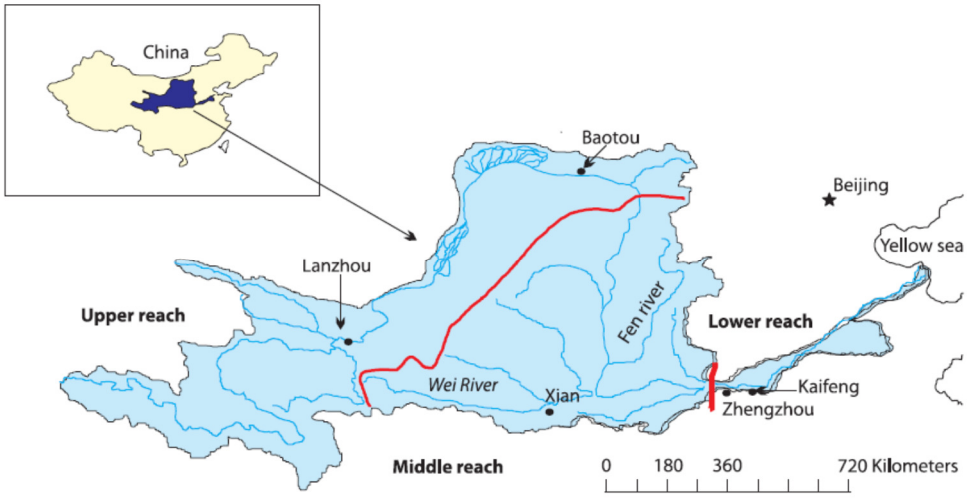

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Fig. 1. Map of the Yellow River basin

2. Current Water resources of the Yellow River

When the Yellow River basin is becoming more and more important for the local economic and social development, lots of problems are arising. For example, water supply and demand cannot reach a balance. Much water wastage is discharged into the Yellow River illegally. Because of severe water shortage, groundwater is overexploited. Meanwhile, severe drying-up is happening. At last, water pollution is also a problem that should be paid attention to. These problems are explained in detail in the following sections.

2.1. Supply of and demand for water resources of the Yellow River

Since 1970's, growing industrial and agricultural activities have been demanding more and more water resources from the Yellow River, and the scarcity of water resources, especially in the downstream region, has been worsened. The total water consumption of the Yellow River for industry, agriculture and daily life was 38,9 Bm^3 (billion cubic meters) in 2002 and 52 Bm^3 in 2010 [38]. The total water consumption increased by 1.09 Bm^3 (million cubic meters) every year on average, but the yearly water supply of the Yellow River basin and interior drainage basins was only 73,8 Bm^3. It is proved that more than 40 % of the threshold water utility rate can cause serious environmental, social and economic problems [38].

In the basin, only 593 m^3 of water is available per person, which is 23 % of Chinese national average and 6.25% of the world average. Similarly only 4,860 m^3 is available per hectare of arable land, 18 % of Chinese national average [5]. At the same time, the yearly growth rate of the population in the region is over 12 % during the last 50 years, which is the major driving force for increase of water demand and water use. The Yellow River Conservancy Commission estimates that by 2010, the total water consumption may reach 52 billion m^3 per annum, leading to a shortfall of more than 10 billion m^3, given 42 billion m^3 available for supply in a moderately dry year [1]. Therefore, the deficit of the water resources of the Yellow River will be aggravated in future.

2.2. Low utility rate and overexploitation of groundwater

Water resources are overexploited in the Yellow River basin. In most irrigation districts, lack of financial support from the public sector results in deterioration of irrigation infrastructure. The obsolete irrigation methods, poor canal system and low water prices cause the serious waste of water. As the water is required more and more for industrial use and daily life in cities, over-withdrawal of groundwater is very serious (Table 1), especially in the Shanxi and Shaanxi provinces, which have suffered thirty-four and eighteen groundwater depression cones, respectively (Fig. 2) [34]. Over-withdrawal of groundwater also causes land subsidence. From 1959 to 1989, 200 km^2 in the area surrounding Xi'an, the capital city of Shaanxi Province, had subsided due to overexploitation by as much as 1,8 meters — nearly six feet. Similarly, over 250 km^2 surrounding Taiyuan, the capital of Shanxi Province, has subsided by as much as 2,6 meters [15].

Table 1

Water uses by sector by source in the Yellow River Basin in 2012 (Unit: 10^8 m^3)

Province	*Program*	*Total*	*Surface Water*	*Underground Water*
Qinghai	Withdrawals	14,48	12,54	1,94
	Depletion	10,09	9,02	1,07
Sichuan	Withdrawals	0,35	0,34	0,01
	Depletion	0,26	0,25	0,01
Gansu	Withdrawals	47	40,51	6,49
	Depletion	36,55	31,88	4,67
Ningxia	Withdrawals	71,85	66,39	5,46
	Depletion	41,31	37,55	3,76
Inner Mongolia	Withdrawals	97,41	67,35	30,06
	Depletion	76,51	53,94	22,57
Shaanxi	Withdrawals	64,60	34,58	30,02
	Depletion	49,53	27,72	21,81
Shanxi	Withdrawals	48,79	23,85	24,94
	Depletion	39,42	20,66	18,76
Henan	Withdrawals	80	56,77	23,23
	Depletion	70,75	53,86	16,89
Shandong	Withdrawals	92,32	83,84	8,48
	Depletion	87,9	81,62	6,28
Hebei, Tianjin	Withdrawals	6,8	6,8	0
	Depletion	6,8	6,8	0
Total	Withdrawals	523,60	392,97	130,63
	Depletion	419,12	323,30	95,82

Source: 2012 Yellow River Conservancy Commission Water Bulletin

Table 2

Statistics of groundwater funnels in the Yellow River Basin in 2012

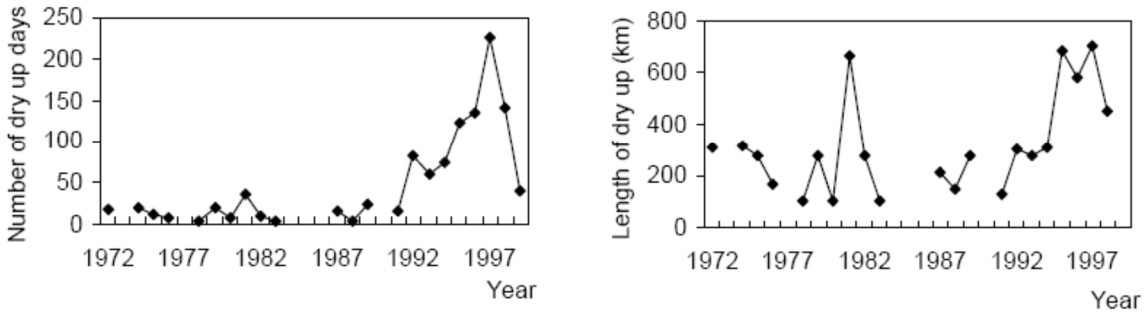
Name	*Location*	*Feature*	*Area (km^2)*	*Depth (m)*
Yinchuan funnel	Ningxia	shallow groundwater	439,36	18,72
Dawukou funnel	Ningxia	shallow groundwater	61,32	58,34
Fengdong funnel	Shaanxi	shallow groundwater	22,09	27,16
Xinghua funnel	Shaanxi	shallow groundwater	19,41	13,94
Luqiao funnel	Shaanxi	shallow groundwater	8,13	29,38
Xi'an funnel	Shaanxi	shallow groundwater	193,66	102,24
Xianyang funnel	Shaanxi	shallow groundwater	12,29	33,10
Duqiao funnel	Shaanxi	shallow groundwater	3,6	18,78
Songgu funnel	Shanxi	shallow groundwater	120	89,26
Taiyuan funnel	Shanxi	shallow groundwater	85	107,42
Yuncheng funnel	Shanxi	shallow groundwater	2021	108,2
Wushe-Wenxian-Mengxian funnel	Henan	shallow groundwater	460	26,25

Source: 2012 Yellow River Conservancy Commission Water Bulletin

Fig. 2. The distribution of groundwater funnels in the Yellow River basin

2.3. Severe drying-up in the Yellow River

The river flow has reduced so much that no-flow and nearly no-flow events occur frequently. Since 1990's, no-flows in the downstream of the Yellow River have become worse and worse, which is characterized by earlier occurring in the year, longer duration, higher frequency and more extensive coverage [2] (Fig. 3). To date, the worst year for no-flow events was 1997, during which no water flowed into the sea for 226 days. That year, the maximum no-flow river length was 700 km, almost equal to the entire length of the Lower Yellow River [1]. Low flows cause water shortages, and increase sedimentation, thus raising the riverbed level and bringing about an increased risk of flooding. Consequently, seriously reduced flows produce serious impacts on social-economic development and people's daily life in the mid- and down-stream region.



Source: [5]

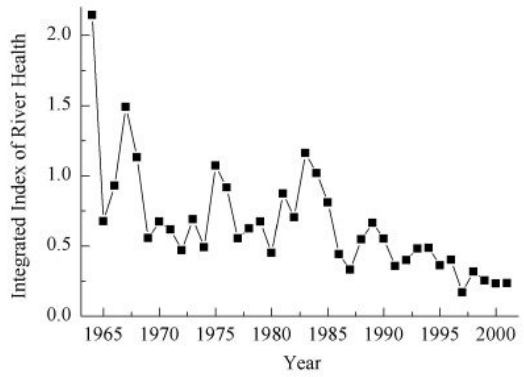
Fig. 3. Duration and length of drying-up in the Yellow River

2.4. Pollution of the water resources

The Yellow River Conservancy Committee, affiliated to the ministry of water resources, said 33,8 % of the river system's water sampled in 2007 registered worse than level five. That means it is unfit for drinking, aquaculture, industrial use and even agriculture, according to criteria used by the UN Environment Programme. Only 16 % of the river samples reached level one or two, the standard considered safe for domestic use. The report said waste and sewage water discharged into the system last year totalled 4,29 bn tonnes. Industry and manufacturing made up 70 % of the discharge into the river, with households accounting for 23 % and just over 6 % coming from other sources (Branigan, 2008). In addition, the continuous increase in wastewater dis-

charge into the river is exacerbating the conflict between water demand and supply [31]. It can be concluded that the water resources is in very poor condition in the Yellow River Basin.

Based on the water shortage and deteriorated water quality, the water demand essential for the river ecosystem could not be satisfied. Even though runoff has sharply decreased, extreme flood events have continued unabated, which indicates that the normal river functions of the Yellow River have been severely impaired. Figure 4 shows the behavior of the river health index in the period from 1964 to 2001. It is obvious that the condition of the Lower Yellow River has declined drastically since the 1960s. For the river to be sustainable, the index must have a value of at least one unity [1]. It can be confirmed that the Yellow River system is not healthy enough to meet the primary ecosystem and socio-economic functional requirements.



Source: [1]

Fig. 4. Integrated River Health Index for the Lower Yellow River since 1964

3. Current Status of Water Management in the Yellow River Basin

3.1. Unclear-Cut Division of Responsibilities

The Yellow River Conservancy Committee (YRCC), as a vice-ministry-level institution directly under the Ministry of Water Resources (MWR), is the syncretism of enterprise, government and public service, and consists of 19 bureaus (or vice-bureau-level) and 15 county-section-level affiliated agencies. It has extensive power on water administration, and also undertakes a great deal of research and design tasks. At the same time, it is still engaged in resources development, engineering construction and production management. However, the powers of YRCC for basin management and planning were limited and unclear in practice [8]. Instead, a wide range of environmental, agricultural, construction, and other agencies along with YRWCC have had overlapping functions and authority while at the same time national, provincial and local agencies have been able to place varying claims and priorities on the river's resources and development.

While The Yellow River Basin Water Resources Protection Bureau (YRBWRPB) is a part of the YRWCC, but is also under the leadership of both the Ministry of Environmental Protection of China (MEP), who oversees water pollution control including water quality monitoring, and the Ministry of Water Resources of China (MWR), who is responsible for the overall water management of China, including surface water and ground water [13, 29]. The YRWCC and the YRBWRPB are mainly responsible for flood control, sediment control and drawing up the comprehensive basin water resources planning, but they have no authority in the administration and economic affairs. On the other hand, the departments of water resources at the provincial, city and county levels of governments are responsible for overall water management under their corresponding administrative jurisdictions and have the power of administration management and economic administration [13, 36].

At the same time, the China Geological Survey, under the Ministry of Land and Natural Sources, is still playing an important role in groundwater monitoring and technical management and advises the Ministry of Water Resources on the groundwater planning and ground water permit management, but no longer issues ground water permits [10, 31]. This results in the fact that the basin organizations and the local government hardly coordinate in processing water environmental protection problems. This phenomenon is called "water resources managed by many departments", "policy made by various organizations", and "everyone's responsibility but everyone's inability".

3.2. Slow Implementation of Water Laws and Regulations

The 1988 water law provides the basic framework and principles for water management in the 1990s. This was followed by related legislation including the Water Pollution Prevention and Control Law, the Soil and Water Conservation Law, and the Flood Control Law. In 2002, the 1988 Water Law was revised to implement a series of key changes in water management [16, 19]: (1) River basin management was explicitly included as part of administrative regional level management (Art. 12); (2) the central government should take full control over all water resources management and uses (Art. 47); (3) ecological water use was given high priority in water allocation decisions (Arts. 9/21).

In addition to the water laws, a large body of additional administrative rules and ministerial regulations related to water, such as Administration of the Price of Water Supplied by Water Conservancy Procedures (the National Development and Reform Commission and the MWR, 2003), Guidance on Water Rights Transfer Demonstration Works in Inner Mongolia and Ningxia (MWR, 2004), Notice on Pro-

moting Water Pricing Reform Promoting Water Savings and Protecting Water Resources (the State Council of China, 2004), Management Regulation on Water Withdrawal Permits and Water Resources Fee Collection (No. 460) (the State Council of China, 2006) were also passed along with a number of other laws at least indirectly related to water including The Environmental Protection Law, The Land Administration Law, the Fishery Law, the Forestry Law and the Mineral Resources Law [6, 8, 25]. In addition, local governments are called upon to develop plans for the implementation of these laws and regulations, based on local socio-economic and natural background. The implementation is always slow for several reasons: (1) there is no specific organization which takes charge of investigating and enforcing the liability resulting from the implementation of water laws and regulations; (2) local governments do not give high priority on the implementation of water laws and regulations; (3) local governments possibly meet difficulties on deciding how to implement water laws and regulations, such as financial difficulties and political infighting [28]; (4) the legal system of water management is dominated by regulations but not laws, while regulations are very newly issued and do not provide detailed implementation provisions [24].

3.3. Imperfect Water Pricing System for Irrigation

The Chinese government introduced wide-ranging reforms in water pricing in the early 1980s, including the volumetric pricing of irrigation water. A two-tier system of payment for irrigation water was applied, including a basic charge and a volumetric water fee. In 2002, the Chinese government implemented a new policy in which the water fee was separated from other taxes and was levied at 0,050 RMB/m^3 by the water management stations. In 2004, the policy was revised again. Under the revised policy, farmers are again charged on a two-tier basis, including an area-based payment of 75 RMB/ha and a volumetric water fee of 0,033 RMB/m^3 [7]. The water price includes the price of water supply and the expense for sewage processing. The total water price should include three parts such as resources price, engineering price and ecosystem-environment price [22]. But the current water price for irrigation do not even cover the full costs of operating and maintaining irrigation systems [12, 26, 32]. That is, China's agricultural water is believed to be much under-priced.

Agricultural water fees are generally collected from bottom to up. That is, the village will collect a water fee from farmers and then submit it to the township, the township will submit the fee to the county and the irrigation district will take a share of this water fee from the county. Some difficulties are met in collecting agricultural water fees because farmers are reluctant to pay for water due to budget constraints when they believe that they are receiving poor service. Consequently, only part of water fees can be collected and the inability to collect fees on time may become a long-term problem [24].

4. Why to implement Integrated Water Resources Management (IWRM)

However, there are as many obstacles standing in the way of the realization of IWRM in the Yellow River basin as there are opportunities in support of it. Here three areas of interest are discussed.

It will be very essential to apply the IWRM approach in the Yellow River basin where there are so many serious problems existing in the Yellow River basin. Aimed at sustainable development, the IWRM approach can promote more coordinated development and management of surface water, groundwater, river basins, and upstream and downstream interests. The IWRM has arisen as distinct from narrow-departmental water use, which results in inefficient water management. The IWRM approach can facilitate to overcome the water conflicts of water volumes, water supply schedule and water quality, which are incurred by both the spatial and temporal non-uniformity of water use and the poor water infrastructure in shortage of financing. Consequently, it is very necessary for a water management organization to satisfy the requirements of its clients in sustainable, equitable, and high-quality manner and to avoid breaking the balance of "demand-and-supply" [3].

More important in the process of IWRM implementation, it is perhaps unnecessary to seek universal and stereotyped approaches that are acceptable for all water management cases (IWRM ToolBox Version 2, 2003). That is, it seems that the IWRM can be definitely applied in the Yellow River basin and a reasonable IWRM approach should be developed specially for the Yellow River basin.

5. Framework of IWRM in the Yellow River basin

According to [17] there are three major principles in IWRM and these are:

- Sectoral (and sub-sectoral) integration that takes into account competition and conflicts among various users;
- Geographical integration;
- Economic, social and environmental integration that take into account of social, and environmental costs and benefits and

Based on the above principles, five proposals are put forward to promote the IWRM in the Yellow River Basin.

5.1. Legal Framework of IWRM in the Yellow River Basin

A complete legislative system should be set up on the basis of existing "the Yellow River Law" and "the Yellow River Water Resources Management and Protection Regulation", which can ensure the water resources management, pollution prevention,

soil and water conservation, and flood control in a consistent, integrated and participatory manner throughout the Yellow River Basin [14, 33]. The complete legislative system should coordinate the implementation of laws and regulations at different levels, such as "the Yellow River Law", "Yellow River Basin Water Resources Protection Regulation", "Yellow River Basin Water Resources Pollution Compensatory Approach" and "Yellow River Basin Pollution Discharge into River Mouth Management Method". The complete legislative system should (1) clarify many of the ambiguous aspects of national and provincial laws, such as authorities. For example, the authority of the local governments and the river basin management organizations should be clearly defined. It should also clearly demarcate the authority of environmental protection agencies versus the role of water administrative organizations in aspects of water management, such as water quality monitoring. (2) Allocate duties where these are contested at operational levels, like The Water Pollution Prevention and Control Law, and financial arrangements for local governments should also be specified. YRCC should be legislated to the chief organization of water administration. (3) Coordinate the conflicts of legal provisions. For instance, before it was amended recently, the Water Pollution Prevention and Control Law (Article 18) stipulated that water resource protection agencies in river basins are responsible for monitoring and evaluating surface water quality and reporting to SEPA and MWR. However, the Water Law (Article 32) requires that the water bureaus of the local governments above the county level and river basin organizations be responsible for monitoring water quality in water function zones and report to local governments and environmental protection agencies. (4) enable accessibility to data and data sharing; (5) and provide for public involvement and freedom of information [18, 30]. Finally, the law on water fee collection should be set up so that the water fee can be levied on by an integrated method.

5.2. Institutional Framework of IWRM in the Yellow River Basin

Introducing IWRM requires in the more extent of institutional and social reforms rather than engineering ones, although the engineering measures are the important component. IWRM application depends upon effective and transparent governing institutions.

To innovate the water administration and management system, it is necessary to distinguish the development organization from administration organization. The development organization is responsible for the utilization and development of water resources, drafting comprehensive planning after investigation and assessment of the water resources, verifying and approving the special planning of water resources, employing the latest technology for water resource development, and supervising the development of water resources. The YRWCC can be development organization. The administration organizations are the representatives of the state and are responsible for the management of water rights, including clarification, protection and supervision of water rights, procedure for obtaining water right, appraisal and monitoring of water metering facilities, transferring and transacting water rights, and judging water right disputes [35].

Water permission system should transit into water right system. Management notion should shift from "administrative order + coordination" to "self-maintenance + equal negotiation". Quantity and quality control system, including water division agreement and sectional water quality control agreement, should be set up. Water utilization range should be defined. Water transfer scheme and corresponding coordination mechanism should be made to realize the integrated management of surface water and groundwater, trunks and branches. The mechanism that water right owners equally participate in the management should be introduced. Priority system for water permission should be established. The water permission system should be checked and accepted yearly. Supervision of water permission system should be enforced.

Tariff system should be perfected as well. Supply and demand mechanism should be used to adjust various water expenses. The principle of "price double above quota" should be applied in order to encourage water saving. Pollution discharge permission system should be implemented completely and it is necessary to build up pollution discharge trading market for adjusting pollution discharge, which must be strictly supervised and managed by the government. According to the rule of "whoever discharge pollution or bring damage to environment should pay", water resource protection economic considerations mechanism should be set up. The polluter is to undertake the total cost for harnessing pollution and to pay extra compensation for the polluted water that loses all or most of its function.

The legal status and the power of the YRCC and the YRWPB should be ascertained and strengthened. The basin organization should be powered with the integrated water transfer and allocation right, drawing up water allocation and transfer plan as soon as possible on the basis of the water allocation scheme approved by the State Council in 1987 in order to solve the problems concerning water supply, ice jam prevention and electric power generation [11]. The relationship between the basin organizations and related local departments should be coordinated by the Ministry of Water Resources. The necessary policy and professional training should be carried out in the basin organizations.

Moreover, in the water resources protection management organization, the representative of the central government should be in the leading group, and the representatives of related administrative department of the central government, provincial government, major cities and economic regions, main customers and polluters should also participate in leadership [36].

5.3. Market Framework of IWRM in the Yellow River Basin

Currently, the Yellow River water market is not an absolute market, only a semi-market. The so-called semi-market means that, giving attention to flood control, generating electricity, shipping, ecological water demand, basic water demand in all the areas and other water demands, water resources are allotted according to the market principle among provinces (areas) or departments, which is the water supply market with both macroscopic and microscopic perspectives.

The Yellow River water market is characterized by the following traits which are disadvantageous for the optimizing configuration of water resource in the Yellow River basin: water exchange is restricted by the spatio-temporal distribution of water resources; only the users bringing economic benefit into play can enter the market; The exploitation of water resource has much to with local economic development, which leads to the partial competition between different areas and customers; water goods, water access and managerial authority can be on the onerous move only under the government's permission.

Therefore, a market characterized by the following traits should be built up in the Yellow River basin: various uses of water can enter the water market and government should transfer power to a lower level, not interfere water trade. The frame of water market of the Yellow River basin can be referred to Fig. 5.

Large water supply companies like Zouping water supply limited liability company of Yellow River, hydraulic engineering like south-north water transfer, large industrial and mining enterprises drawing water directly from the Yellow River such as Baotou steel & thulium company, China Great Wall aluminum company, Central plains oil-field, Shengli oil-field, irrigation areas drawing water from the Yellow River such as the Great Bend of the Huanghe River irrigation area, the Fen and Wei irrigation area, downstream irrigation area and others.

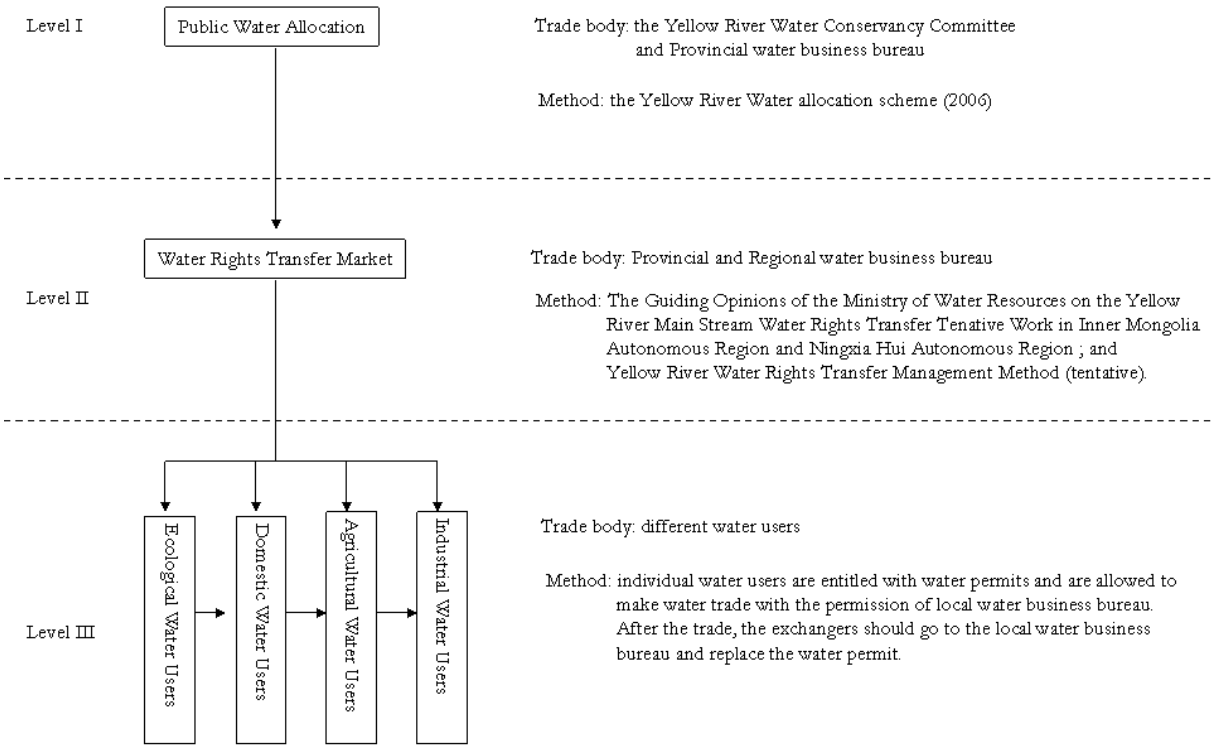


Fig.5. The frame of water market in the Yellow River basin

To establish water price formation mechanism being suitable for China, it is necessary to make it clear that water is a commodity and water price is determined on the basis of cost, reasonable profits and fair partition. Then according to the current national finance system and relevant provision about water supply cost expenses, we need to check correctly and ascertain water supply cost expenses. Subsequently, by taking into account the recovery of investment cost, a water price formation mechanism that can both attract investment and stimulate the interest in water saving should be built up. Finally, a normal water price adjustment mechanism should be established that can adjust water price according to the change of the costs in time [37].

It is also urgent to build up an effective price management system, including the following contents [37]. Firstly, for different consumers with different purchase capability and different water accessibility, the water price should be adjusted under the general goal of national macroscopic readjustment and control. For example, in the irrigation area with poor agricultural production conditions and infrastructure, some subventions, especially visible and direct ones to the farmers, are necessary to reduce indirect and intermediate subsidy. Financial policy may be another effective method for agriculture. Mid- and long-term loans and agricultural policy financing in the form of discounted interest are necessary as well as the perfection of the law and regulation system on agriculture. Secondly, scientific classification system of water price is necessary for different users, according to the request of the national industrial policy, to save water. Basic water price are to be established while in some areas seasonal water prices are to be adopted. The corresponding marginal cost will rise for increased water supply and water price is higher in summer than other seasons [27]. Thirdly, water price reform is to be enforced with the reform of water conservancy management system. For example, inter-regional and trans-business water supply company for both urban areas and suburban areas may facilitate the water price reform because such kind of corporation can adjust water price for different parts of a river. Fourthly, stratified water price management is recommended [27].

5.4. Engineering framework

Fund is the foundation for effective implementation of laws and policies. According to the actual conditions of the Yellow River basin, the following measures can be taken. The central government of China should devote more investment to soil and water conservation, water pollution prevention and control and water-saving irrigation. The central government invested RMB 2,994 billion in 2009 for water and soil conservation engineering construction in key soil erosion areas, such as the upper and middle reaches of the Yangtze River and the Yellow River, which only accounted for less than 0,01 % of GDP of China. More investment, by local government or the central government, is needed in the future and priority is to be made. Foreign loan is an important way for water resource management, though the guarantee by the government may be needed. Gansu Province is successfully implementing the World Bank loan project "western China anti-poverty". With the completion of this project in 2006, a total of 84,7 millions dollars will help more than 1 million people in Tianshui, Dingxi, southern Gansu Province and Pingliang of Gansu to get rid of the poverty. The project of Xiaolangdi is the first water electricity project using World Bank loan in China that implements environment management according to the international practice. Many kinds of administrative and economic methods such as revenue, rewarding and allowance are introducing enterprise fund into water resources protection. Furthermore, funds can be raised from the society through multiple channels such as water resource charges, water rate, pollutant discharges and water resource pollution compensations. As an economic entity and independent legal representative, River basin organization is responsible for the construction, management and operation of the comprehensive utilization project in the basin. For instance, a river water resources development group based on the Xiaolangdi Hydro Project Construction Management Bureau is possible so that it can operate as an enterprise (Xiaolangdi Hydro Project Implementation Bureau, Ministry of Water Resources 1998).

The metering facilities should be examined and supervised so that problems can be solved in a timely manner. Monthly and yearly statistical system of the Yellow River should be set up and perfected to provide reference to the integrated management and scientific allotment of water resources in the Yellow River basin, and is beneficial to the implementation of effective supervision and management on water users (Meng *et al.*, 2002).

In order to meet the needs of economic development and taking into consideration of the characteristics of agricultural water utilization, the price formation mechanism and management method of the agricultural water should be perfected. The first thing is to standardize the compensation mechanism of agricultural water supply and to incorporate the water price for agricultural use into government management. State-owned hydraulic engineering supplies agricultural water determined price by government which is the compensation of reasonable water supply costs and is adjusted by the change of costs. For medium- and small-scale hydraulic engineering that are not owned by government, the government price may be referred. The second thing is to find a mode for water price management according to local conditions and to strengthen the cost assessment and water price

management in towns and townships. In the artesian flow irrigation area where water is withdrawn from rivers and reservoirs, the price can be determined as the sum of water supply price of government-owned water management unit and last level canal system maintenance cost. The last level canal system maintenance cost is the reasonable cost to maintain and protect the canal system. Standardized management and strict control of the standard are needed in the process. Under the canal conditions in highlift area and electromechanical well irrigation area, the management of government-owned water management department has already extended to peasants' field, water price can be checked and ratified to the households and the water rate is collected directly by the water management unit. The third one is to introduce different price for different areas during different seasons, which may be suitable for certain water resources conditions and water supply facilities. In the area where irrigation water is metered, seasonally different price or flexible price may be introduced in order to use price as an incentive mechanism for saving water and alleviating the paucity of water resources. Fourthly, in order to promote the rational distribution of water resources and to keep the steady operation of the hydraulic facilities, the two-part water price system of quantity price and capacity price should be further spread. In this case, the water-saving consciousness of the farmers can be improved and water-saving agriculture can be reached with the consideration of farmers' purchase capacity.

5.5. Public participatory framework

The public should be allowed to influence the outcome of plans and working processes. "The public referes to one or more natural or legal persons, and, in accordance with national legislation or practice, their associations, organizations or groups" (SEIA Directive (2001/42/EC), Aarhus Convention Art. 2(4)). Effective public participation in the taking of decisions enables the public to express, and the decision-maker to take account of, opinions and concerns which may be relevant to those decisions, thereby increasing the accountability and transparency of the decision-making process and contributing to public awareness of environmental issues and support for the decisions taken [21]. Therefore, the managers and decision-makers should recognize the importance of public education and participation and make efforts to encourage the public to participate in managing and protecting water resources. Several methods are recommended. Firstly, the status quo of water resources in the Yellow River basin should be disseminated to the public in time, such as water quality, water quantity and water resources development so that people are clear about the water situation. Secondly, environmental education to the public should be carried out frequently in order to raise their environmental awareness. Knowledge on water resources should be communicated to the people in the form of reports and exhibition through various media, including TV, Internet and newspapers. The public should be encouraged to behavior environmentally friendly. The public should be supported to join water protection activities. Thirdly, water resource laws and regulations should be clarified to the public on "World Water Day" and in the "China Water Week". At last, the public should be allowed to participate in making some laws and regulations on protecting water resources in the Yellow River. Hearing should be held after designing a new law or regulation before it is put into practice.

6. Conclusion

The water resource crisis in the Yellow River basin is becoming increasingly serious, which is manifested not only in water shortage, but also in the deterioration of water quality, the reduction and loss of the function of water bodies. Strengthening water resources protection and management has already become an extremely urgency. The IWRM approach is very in need for improving the water situation in the Yellow River basin. Since there is no stereotype IWRM approach, a framework of IWRM approach suitable for the Yellow River should be designed. Legal aspect, institutional aspect, market and public participation are explained and discussed in the paper. This paper can cover the research gap in this field to some extent and offer some instructive proposals for decision-makers and scientists. Definitely, more work should be done in the follow-up research in order to detail every aspect of the whole framework, which cannot be completed in one paper.

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